Tropical Cyclone Vulnerabilities in Micronesia: An Update

Chip Guard
Warning Coordination Meteorologist

29-30 April-1 May 2009

MISSION STATEMENT

- PROTECT LIFE AND PROPERTY
- PROMOTE THE NATIONAL WELFARE AND ECONOMY
- HOW DO WE DO THIS? We issue forecasts and warnings, and ensure that customers understand them

WFO GUAM FACILITY

- Built to withstand 194-mph winds
- Meets seismic zone 4 earthquake requirements
- Emergency power & water; cooking and washing facilities
- Hardened & Backup communications
- Environmentally sensitive
- Occupied 4/9/2000

WFO GUAM STAFFING

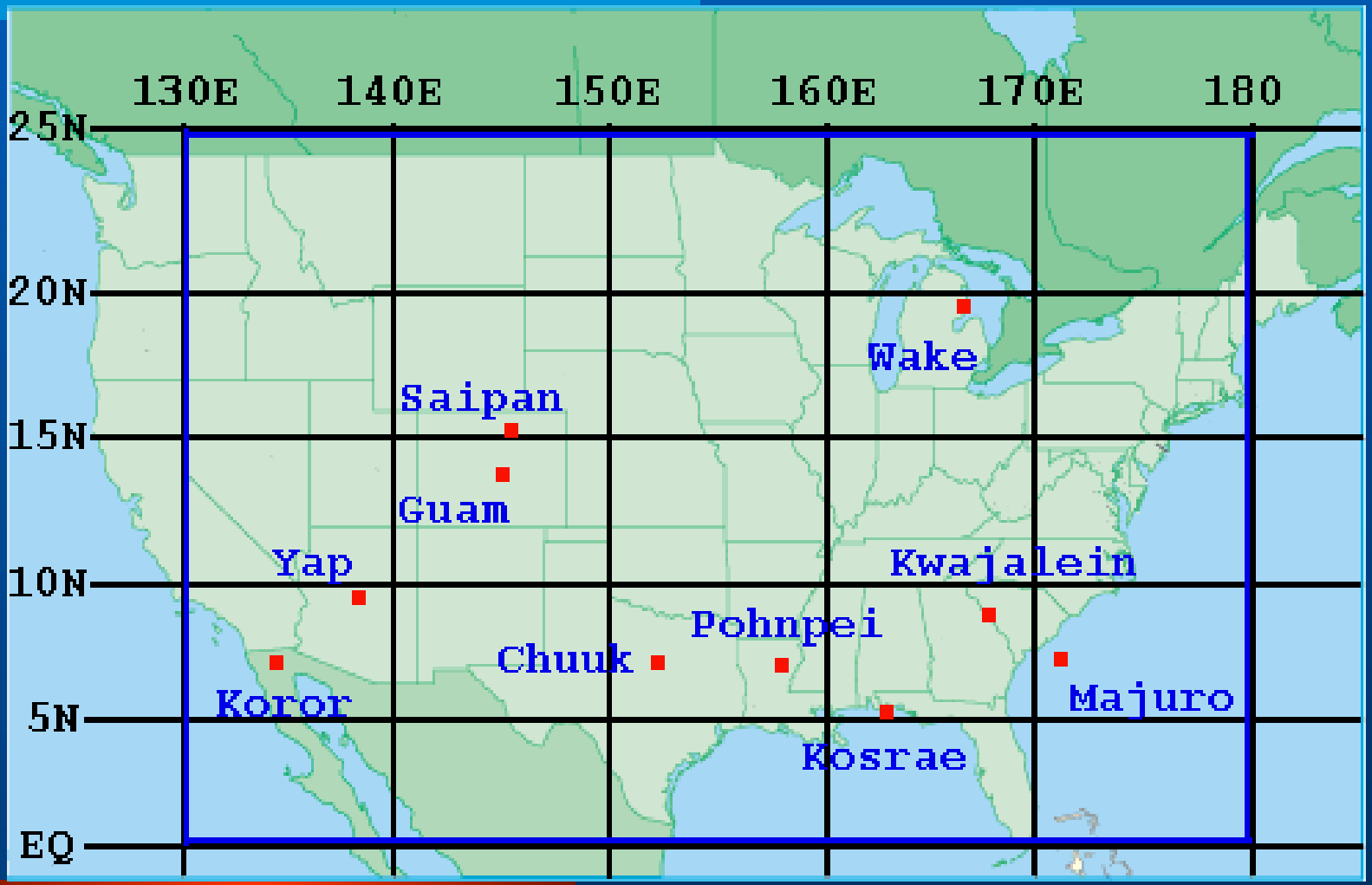
- 1 Meteorologist-in-Charge
- 1 Administrative Assistant
- 1 Warning Coordination Meteorologist
- 1 Science and Operations Officer
- 10 Duty Meteorologists
- 3 Hydrometeorological Technicians + 1 Manager
- 1 Information Technology Officer
- 1 Electronic Systems Analyst
- 4 Electronic Technicians
- 22 years of JTWC experience
- ~100 years of TC warning/TC research experience
- We can help in our “small” 5 million square miles

WFO GUAM'S UNIQUE RESPONSIBILITIES

- Area of Responsibility—4,760,000 square miles
- About 500,000 people
- Mission—National and International in Scope
  - Territory of Guam
  - Commonwealth of the Northern Mariana Islands
  - Three Independent Countries, one with 4 states
    - Federated States of Micronesia
      (States of Yap, Chuuk, Pohnpei, Kosrae)
    - Republic of Palau
    - Republic of the Marshall Islands
- Tropical Cyclone Warnings for 37 Islands
- Hazards: typhoons, monsoons, El Nino, earthquakes, tsunamis, volcanoes, high surf, etc
- World Meteorological Organization involvement

Area of Responsibility

Area of Responsibility



OBSERVATION PROGRAMS

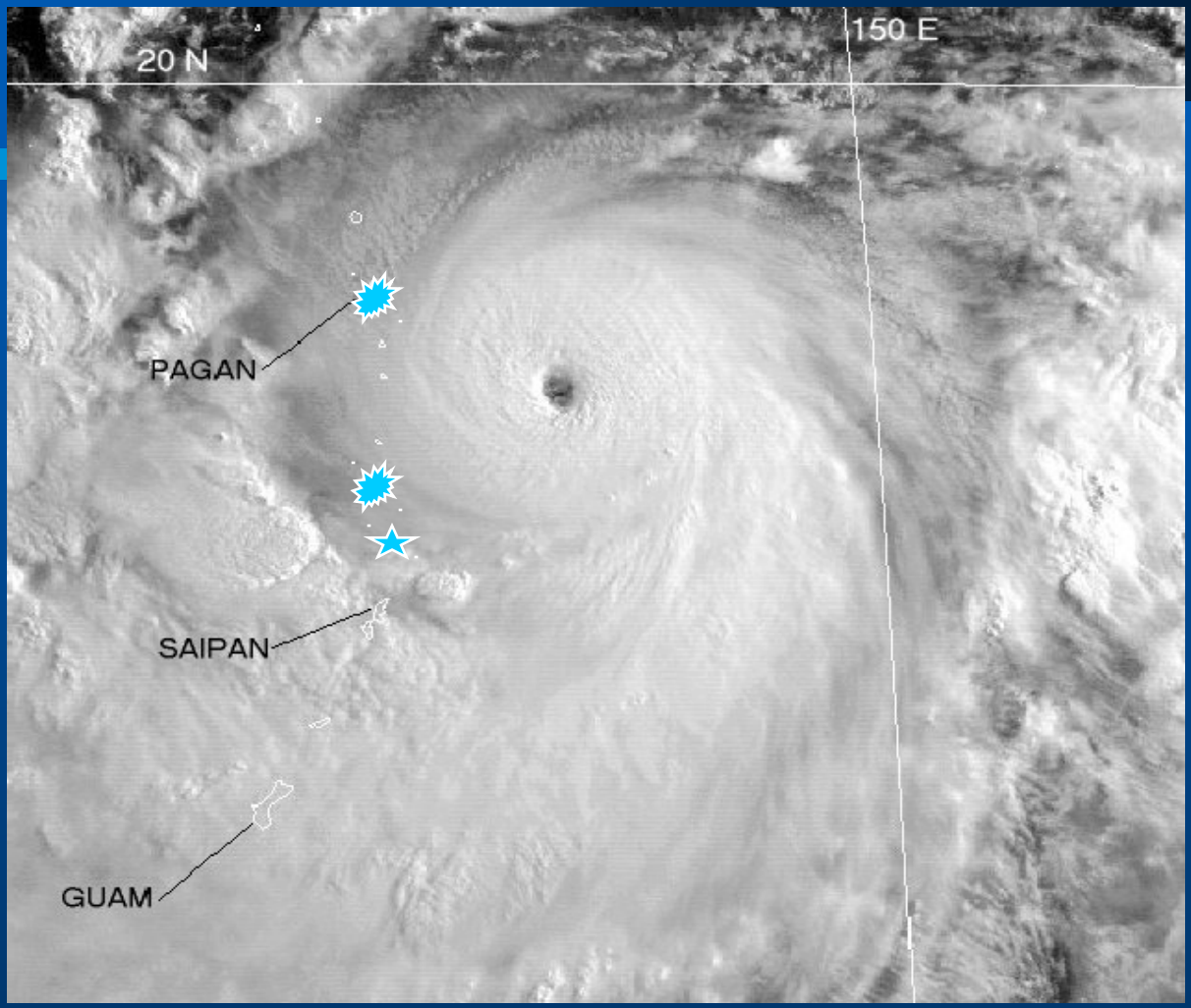
- **Surface observations**
  - **Hourly and special**
  - **Automated Surface Observing Systems (ASOS) at Guam and Saipan**
  - **HANDAR on Guam (4), Rota (1), Tinian (1)**
  - **AMOS—15-year old program; only 1 of 18 still work**
  - **1 research buoy**

- **Upper air observations**
  - **Rawinsonde 0000Z and 1200Z at Guam, Palau, Yap, Chuuk, Pohnpei & Majuro; Kwajalein by US Army**
  - **4 times/day when tropical cyclones are within 300 nm**

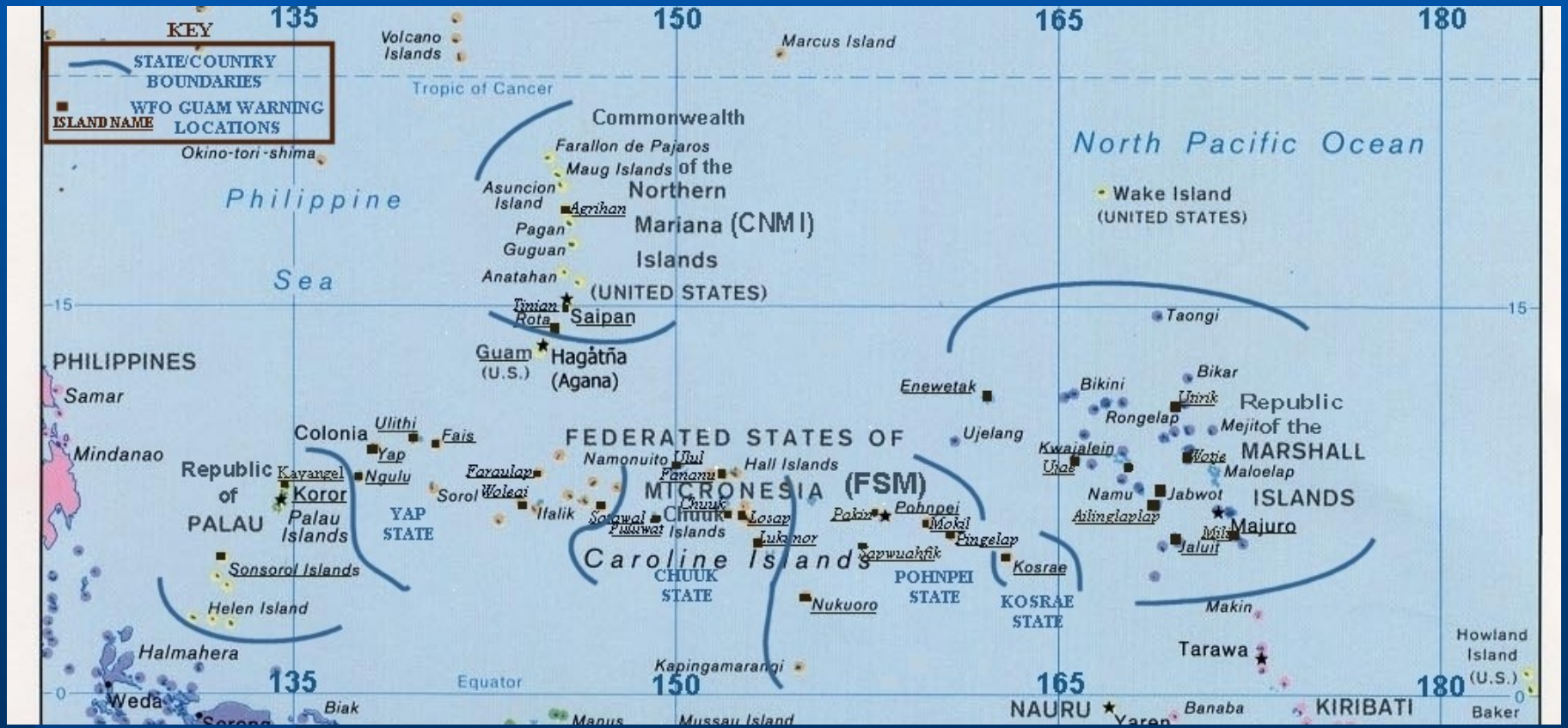
FORECAST & WARNING PROGRAMS

- Public
- Aviation
- Marine
- Tropical Cyclone
- Hydrology
- Fire Weather
- Climate

Tropical Cyclones



Tropical Cyclone Area of Responsibility



37 Warning Points

- Guam
- Commonwealth of the Northern Mariana Islands (4 locations)
- Republic of the Marshall Islands (9 locations)
- Federated States of Micronesia (20 locations)
- Republic of Palau (3 locations)

TROPICAL CYCLONE PRODUCTS

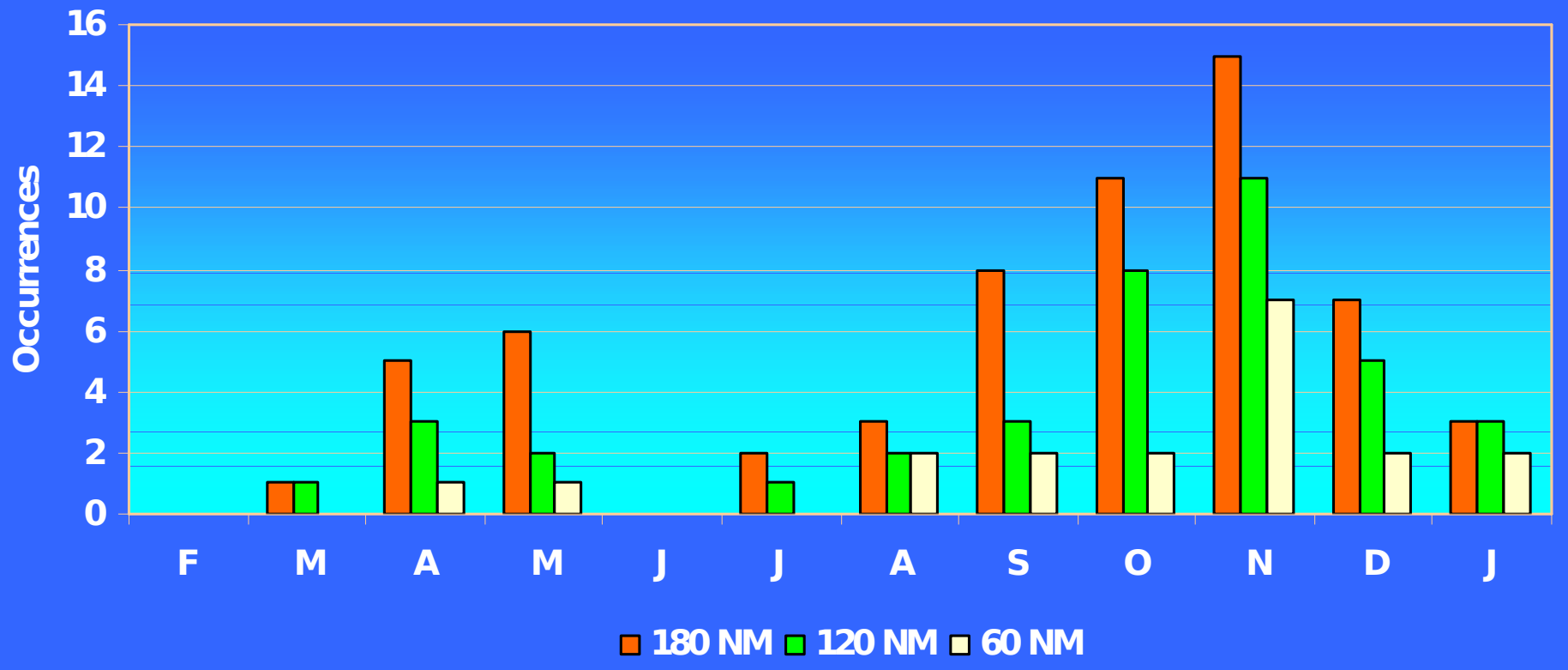
- Tropical Cyclone Public Advisories
- Tropical Cyclone Local Statements
- Tropical Cyclone Position Estimates—Mariana Islands only (based on radar)
- Heavy Weather Briefings for Guam Civil Defense
- Telecom Interface with Weather Service Offices & Disaster Management Offices
- On-island coordination with Air Force and Navy
- Post Storm Assessments

Number of Typhoons within 180, 120 and 60 Nautical Miles of Guam -by Month, 1945-1998

NOTE: Includes Super Typhoons

Within 180 NM: 61 typhoons in 54 years = 1.1 per year

Within 120 NM: 39 typhoons in 54 years = 0.7 per year



Considerations

- People need 8-10 hours of daylight to prepare
- Ships need 36 hours to sortie
- Our advisories are tied to JTWC bulletins
- Away from major islands, communications is via solar powered HF radio; usually twice-a-day contact unless warnings are issued
- Sea level is rising; vulnerability is increasing

Considerations

- NWS bases Watches and Warnings on arrival of damaging winds (34kt/39mph)
- Civilian Disaster Managers base CORs on arrival of damaging winds
- Military sets CORs based on arrival of destructive winds (50kt/60mph)
- More than half of the population in Micronesia lives within 10-15 feet of sea level

TWO TYPES OF ISLANDS

- High Islands
- Low Islands

- Each type of island has specific weather-related problems, especially during El Nino events and tropical cyclones

HIGH ISLAND

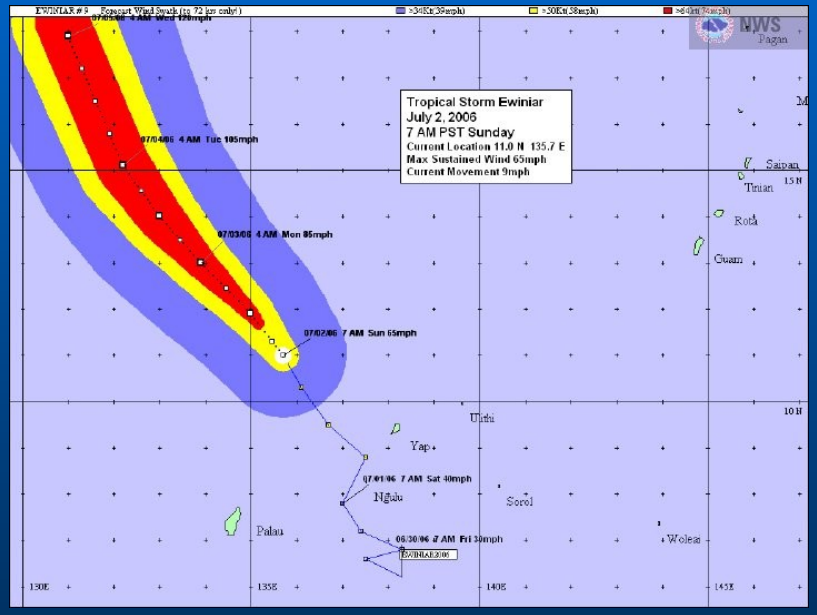
LOW ISLAND

Ebeye, Republic of the Marshall Islands

MAJURO

YAP STATE


TIDE STA


Tropical Storm Ewiniar
July 2, 2006
7 AM PST Sunday
Current Location 11.0 N 135.7 E
Max Sustained Wind 65mph
Current Movement 9mph
07/04/06 4 AM Tue 105mph
07/03/06 4 AM Mon 85mph
07/02/06 7 AM Sun 65mph
07/01/06 7 AM Sat 40mph
06/30/06 7 AM Fri 30mph
EWINIAR 06
NWS
Pagan
Saipan
Tinian
Rota
Guam
Ulithi
Yap
Ngulu
Sorol
Palau
Woleai
10 N
15 N
130E
135E
140E
145E

Recent and Upcoming Changes

- USAID/OFDA Responsible for FSM and Marshall Islands Recovery Support
- Climate Change
- 8,000 Marines are coming to Guam

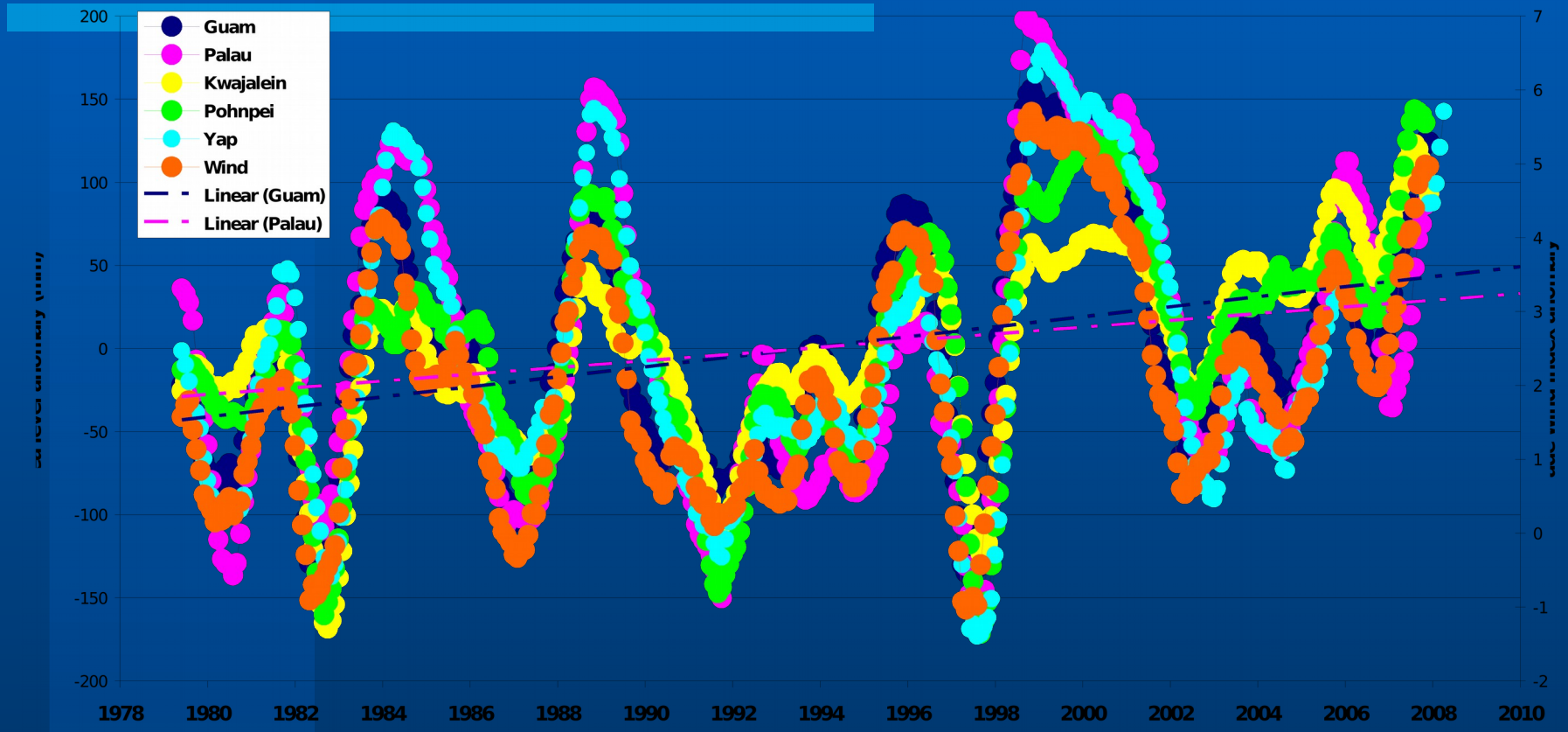
USAID/OFDA Disaster Recovery Support for the FSM and Marshall Islands

- Occurred November 4, 2008
- There will be some changes in recovery and hazard mitigation programs
- Disaster Coordinator located in Majuro
- Regional Office located in Bangkok
- Mitigation programs are being looked into by the Disaster Coordinator
- Learning curve for OFDA and the Islands

Climate Change Considerations

- Eventual Creation of a NOAA National Climate Service—the initiative is in motion; more emphasis on climate
- Climate Change
  - At this time, the effect on tropical cyclone size, number or intensity is a flip of the coin; monsoon and ENSO behavior with a changing climate is still unknown
  - Sea level rise is a reality; vulnerability and risk are increasing; inundation and erosion are increasing
  - La Nina events are also having impacts now
  - Low islands are at the greatest risk
- WFO Guam needs to have good 25-kt and greater wind analyses and forecasts
- WFO Guam needs good sea level (altimetry) data

Pacific Island Sea Level 1978-2008 —Strong ENSO Signal, but Upward



Lander and Jensen,

Marines Coming to Guam

- WFO Guam providing data and studies for DOD environmental impact statements
- Up to 20,000 construction workers will be working on Guam
- 8000 Marines, 9000 Dependents—half will live off-base
- Tinian Training will likely require WFO Guam to set up a Fire Weather Program for the CNMI
- WFO Guam will likely place live firing messages on NOAA Weather Radio
- WFO Guam will likely be requested to provide more safety stand-down briefings for DOD
- WFO Guam provides 2-day Tropical Cyclone, Disaster Preparedness and Climate workshops

StormReady-TsunamiReady

- Guam 2006
- Saipan 2007
- Tinian 2008
- Rota 2009

Decreasing Order of Tropical Cyclone-Related Causes of Deaths in Micronesia

- Most deaths in Micronesia due to mudslides—19 (1997), 43 (2002)—both were during El Nino periods
- High surf (before and after worst typhoon conditions)
- Storm surge
- Wind
- Flash floods (least)

Decreasing Order of Tropical Cyclone-Related Property Damage in Micronesia

- Wind (most)
- Storm surge
- Mudslides
- High surf
- Flash floods (least)

Costliest Locations in Micronesia

- Costs: Function of valuation and vulnerability
- Vulnerability: Function of Risk, Population, and Preparedness, Response & Mitigation
- Most Costly to Least Costly
  - Guam
  - CNMI
  - FSM (Chuuk, Yap, Pohnpei, Kosrae)
  - Marshall Islands (Kwajalein/Ebeye; Majuro)
  - Palau

Any Questions?

Thank you and Si Yu’us Ma’ase!

GUAM

- 175,000 people + 5,000 tourists/day
- ~15,000 military & dependents
- ~2014: ~30,000 military & dependents
- ~20,000 emigrants; many live in substandard structures
- 212 sq mi (1/3 the size of Oahu)
- Best infrastructure in Micronesia; transportation center, education center, commerce center, communications hub for Micronesia
- Many languages spoken

GUAM

GUAM


Commercial Port
Naval Station


No Swimming
遊泳禁止

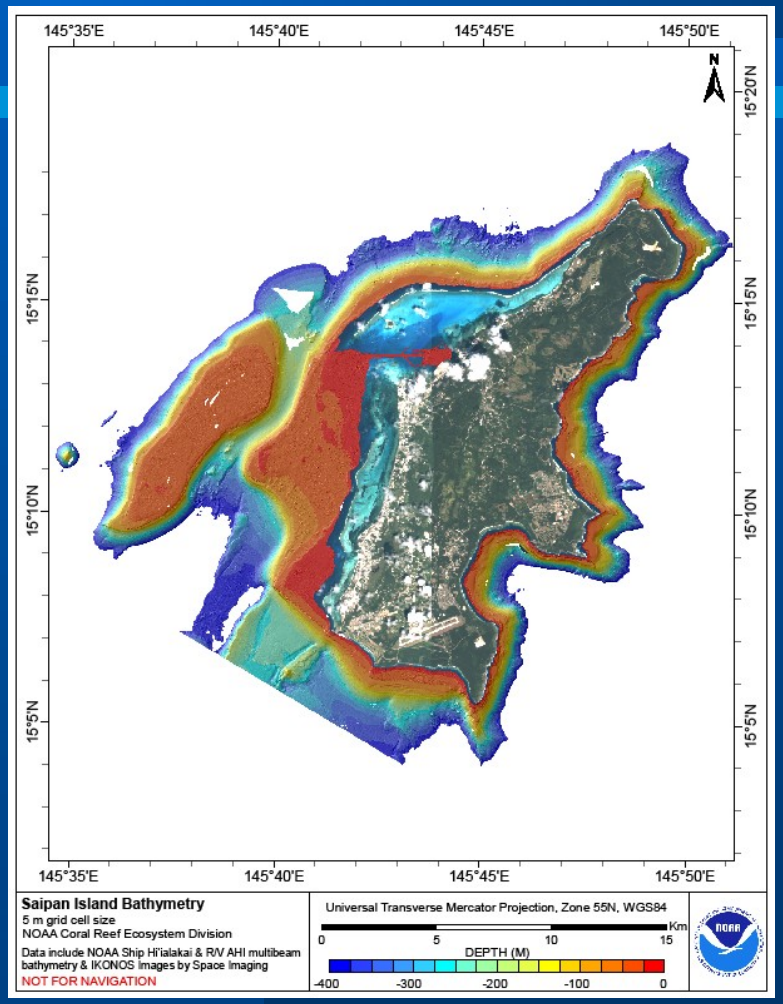

SPIRIT OF FREEDOM

GUAM

Commonwealth of the Northern Mariana Islands (CNMI)

- Saipan is the capital and hub of CNMI
  - 65,000 people + 2,000 tourists/day
  - ~65 sq mi (1/10th size of Oahu)
- 30,000 guest workers; many speak minimal English
- Saipan follows Guam as best developed island and as having busiest port and airport
- Many languages spoken

Saipan



- 4 rapid deployment ships sit just outside the reef on Saipan
- Tinian 4 nm SW; Marines will train there

SAIPAN

SAIPAN

ROTA

opulation: 3,500 + 50 tourists/day Size: ~60 sq mi

TINIAN

Population: 3,500 + 125 tourists/day Size: ~ 60 sq mi

Federated States of Micronesia

- National Government at Palikir on Pohnpei Island
- 120,000 people spread over 2 million sq mi of ocean and ~60 islands
- 4 distinct cultures and 9 languages
- Weather Service Offices (WSO) at Yap, Chuuk and Pohnpei
- WSO Pohnpei handles Kosrae
- Communications are poor, but improving
- Finance: US Compact, tuna, some tourism

CHUUK

CHUUK

CHUUK STATE

- Population: Weno island—35,000; Lagoon—45,000; State—57,000
- Poorest infrastructure and people
- Narrow coastal plain; people live against steep mudslide-vulnerable hills
- Limited water supplies; no rivers and small aquifer
- Weno has 0-4 hrs power/day
- No reliable radio station except at WSO Chuuk—FM station
- Food: Subsistence farming and fishing on outer islands

Tropical Cyclone Storm Surge Vulnerability for Chuuk State

- **Hall Islands—High on windward coastal areas**
- **Namonuito Atoll—High on windward coastal areas**
- **Chuuk Lagoon—Moderate; high for intense tropical cyclones**
- **Mortlocks—High on windward coastal areas**
- **Western islands—High on windward coastal areas**

Tropical Cyclone Wind Vulnerability for Chuuk State

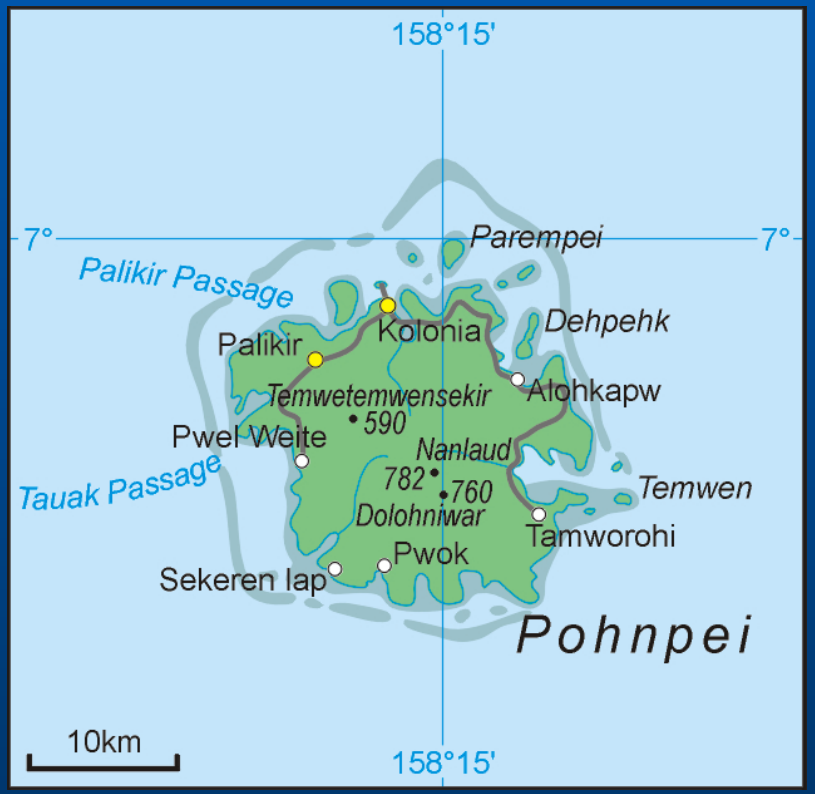
- **Hall Islands—High**
- **Namonuito Atoll—High**
- **Chuuk Lagoon—High**
- **Mortlocks—High**
- **Western islands—High**

Tropical Cyclone Flash Flood/Mudslide Vulnerability for Chuuk State

- **Hall Islands—Low**
- **Namonuito Atoll—Low**
- **Chuuk Lagoon—High**
- **Mortlocks—Low**
- **Western islands—Low**

POHNPEI STATE

Weather Service Office Pohnpei



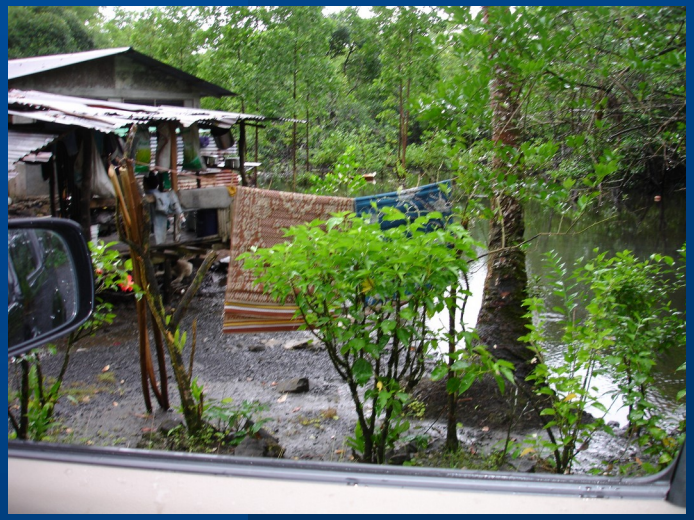
Pohnpei State

- Population: Kolonia—20,000; Pohnpei—30,000; State—35,000
- 2,600’ mountains; 300 inches rain/year; large rivers and waterfalls
- Large flash flood potential around rivers on northeast and south sides
- Large mudslide potential on north and west sides
- 1,000s of people live in mangrove swamps
- Most vulnerable area for inundation is Sokehs
- Port & Airport connected to island by a causeway 4-5’ above sea level
- Pohnpei surrounded by a barrier reef

Tropical Cyclone Storm Surge Vulnerability for Pohnpei State

- **Oroluk—High on windward coastal areas**
- **Mokil/Pingalap—High on windward coastal areas**
- **Pohnpei—Moderate; high for intense tropical cyclones**
- **Nukuoro—High on windward coastal areas**
- **Kapinga—High on windward coastal areas**

Tropical Cyclone Wind Vulnerability for the Pohnpei State



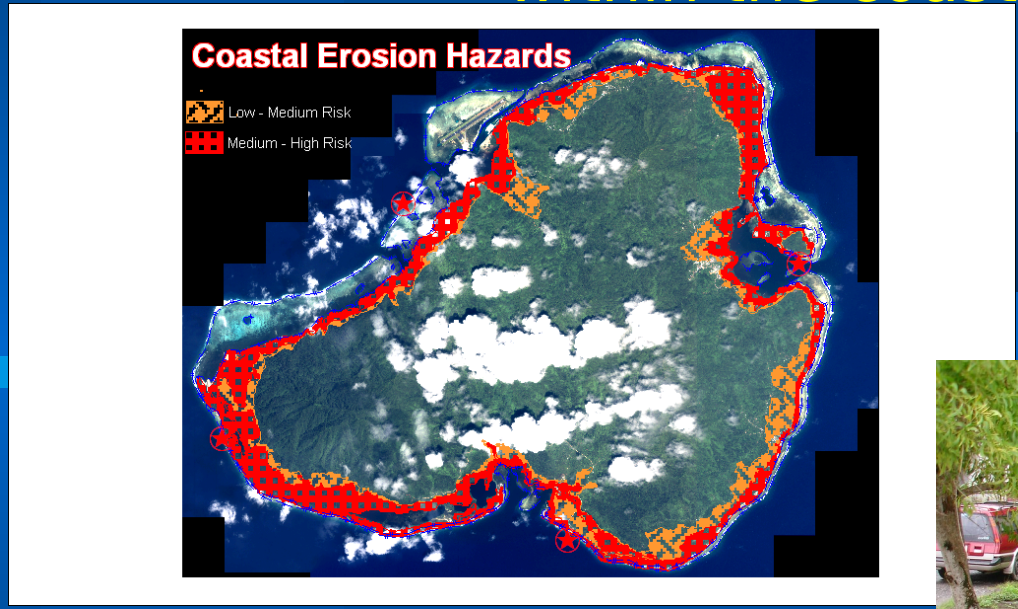
- **Oroluk—High**
- **Mokil/Pingalap—High**
- **Pohnpei—High**
- **Nukuoro—High**
- **Kapinga—High**

Tropical Cyclone Flash Flood/Mudslide Vulnerability for Pohnpei State

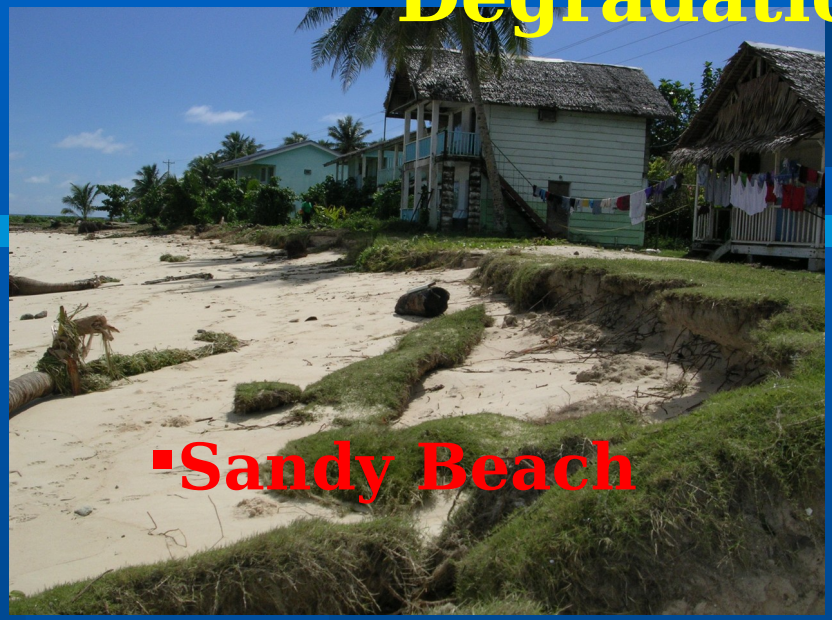
- **Oroluk—Low**
- **Mokil/Pingelap—Low**
- **Pohnpei—High**
- **Nukuoro—Low**
- **Kapinga—Low**

Kosrae State

75% of Kosrae is experiencing coastal erosion. As virtually most of the infrastructures, commercial enterprises & residential properties are located within the coastal zone.



Coastal or Nearshore Degradation



- Sandy Beach

- Tafunsak

- Walung

KOSRAE STATE

- Population: Lelu Is—4,000; State—8,000
- Lelu Is has one 2-lane road, 6’ above sea level linking it with main island
- Many people live at sea level on the island; inundation can produce a lake
- Reefs are very narrow on southeast and south coasts; susceptible from large southern hemisphere swells
- Many small rivers (creeks) that can flood

Tropical Cyclone Storm Surge Vulnerability for Kosrae State

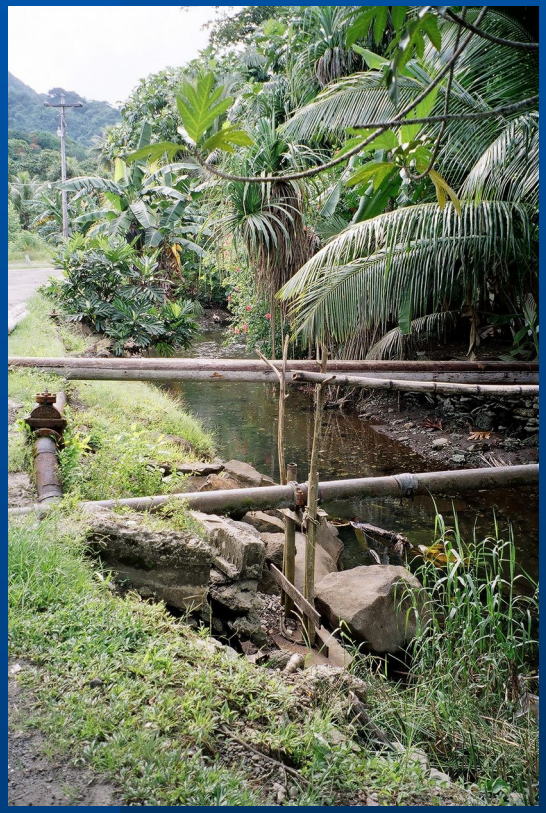
- **Kosrae— High for intense tropical cyclones**
- **Lelu at greatest risk**

Tropical Cyclone Wind Vulnerability for the Kosrae State

- **Kosrae—High**

Tropical Cyclone Flash Flood/Mudslide Vulnerability for Kosrae State

Kosrae High



YAP STATE

YAP STATE

- Population: Colonia—10,000; Yap—15,000; State—20,000
- On east side of Yap, many people live at sea level and are flooded during high waves from the east
- Colonia harbor very vulnerable to wind/storm surge from east to south
- Low islands can be flooded by TCs hundreds of miles away, by weak TCs, and by monsoon surges
- 5 languages

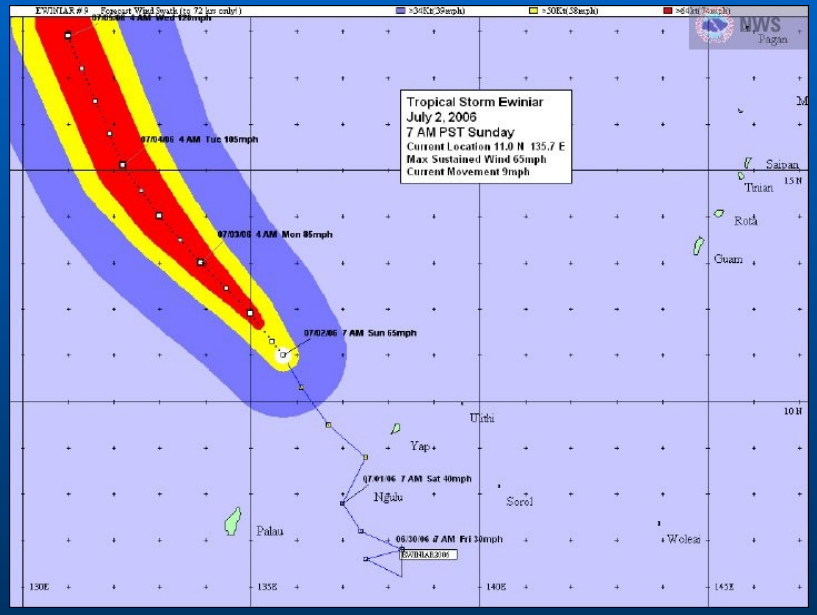
YAP STATE


WEATHER SERVICE OFFICE


Welcome to
National Weather Service Yap
Weather
Service
Office

YAP STATE


TIDE STA


Tropical Storm Ewiniar
July 2, 2006
7 AM PST Sunday
Current Location 11.0 N 135.7 E
Max Sustained Wind 65mph
Current Movement 9mph
07/04/06 4 AM Tue 105mph
07/03/06 4 AM Mon 85mph
07/02/06 7 AM Sun 65mph
07/01/06 7 AM Sat 40mph
06/30/06 7 AM Fri 30mph
EWINIAR 06
NWS
Pagan
Saipan
Tinian
Rota
Guam
Ulithi
Yap
Ngulu
Sorol
Palau
Woleai
10 N
15 N
130E
135E
140E
145E

Tropical Cyclone Storm Surge Vulnerability for Yap State

- **High Islands—High on windward coastal areas including Colonia**
- **Low Islands—High**

Tropical Cyclone Wind Vulnerability for Yap State

- **High Islands—High**
- **Low Islands—High**

Tropical Cyclone Flash Flood and Mudslide Vulnerability for Yap State

- **Yap—Moderate**
- **Low Islands—Low**

REPUBLIC OF PALAU

REPUBLIC OF PALAU

REPUBLIC OF PALAU

- Koror is the most advanced island after Guam and Saipan; has 15,000 people + 400 tourists/day
- Babeldaob is the second largest island in Micronesia; the new Capitol is there
- Koror area is partially protected by a large barrier reef
- Several islands are connected by causeways that are only 7’ above sea level
- The airport is on southern Babeldaob, which is connected to Koror by a high 2-lane bridge
- Kayangel is a low island/atoll at the northern-most part of Palau
- Serious mudslide problem on Babeldaob, Koror

Tropical Cyclone Storm Surge Vulnerability for Palau

- **Kayangel—High on windward coastal areas**
- **Central Babeldaob—High on windward coastal areas**
- **Koror—Moderate; high for intense tropical cyclones**
- **Sonsorol—High on windward coastal areas**
- **Tobi—High on windward coastal areas**

Tropical Cyclone Wind Vulnerability for the Republic of Palau

- **Kayangel—High**
- **Babeldaob—High**
- **Koror—High**
- **Sonsorol—High**
- **Tobi—High**

Tropical Cyclone Flash Flood/Mudslide Vulnerability for Palau

- **Kayangel—Low**
- **Babeldaob—High**
- **Koror—High**
- **Sonsorol—Low**
-

Republic of the Marshall Islands

Republic of the Marshall Islands

- Population: Nation—58,000; Majuro—30,000; Ebeye—15,000
- Extends 1,500 miles
- 55 populated islands; 1 language
- Most islands are less than 10’ above sea level; a few are up to 30’
- Very susceptible to inundation and contamination of fresh water wells

KWAJALEIN

KWAJALEIN

- Population: 50 military + 1000 civilian contractors; 300 local workers during the day
- Transport from Kwajalein to Ebeye is by boat
- Kwajalein has millions of dollars worth of instruments and equipment; need 24 hours to secure or shelter
- Equipment is spread throughout the periphery of the 40-mile wide lagoon

Ebeye, Republic of the Marshall Islands

Ebeye, Republic of the Marshall Islands

- ¼ sq mi—5 football fields long, 2 football fields wide
- 9 feet high
- 15,000 people, mostly emigrants from outer islands
- Cannot build permanent structures
- Roofs held on with rocks and blocks
- Poor infrastructure

MAJURO

MAJURO

MAJURO

- 30 miles from east end to west end
- 30,000 people, but 25,000 live in the eastern 1/3 of the atoll
- When 10’ sea wall is breached, a big lake forms
- Runway catchment supplies water; capacity is 33 million gallons; people use 1 million gallons a day; salt water intrusion will contaminate it
- Highest elevation: 25 feet in western Majuro due to 1918 Cat 4 typhoon that killed around 250 people
- A Cat 3 typhoon hit in 1907 killed over 100
- You can throw a rock from the lagoon to the ocean on many parts of the island

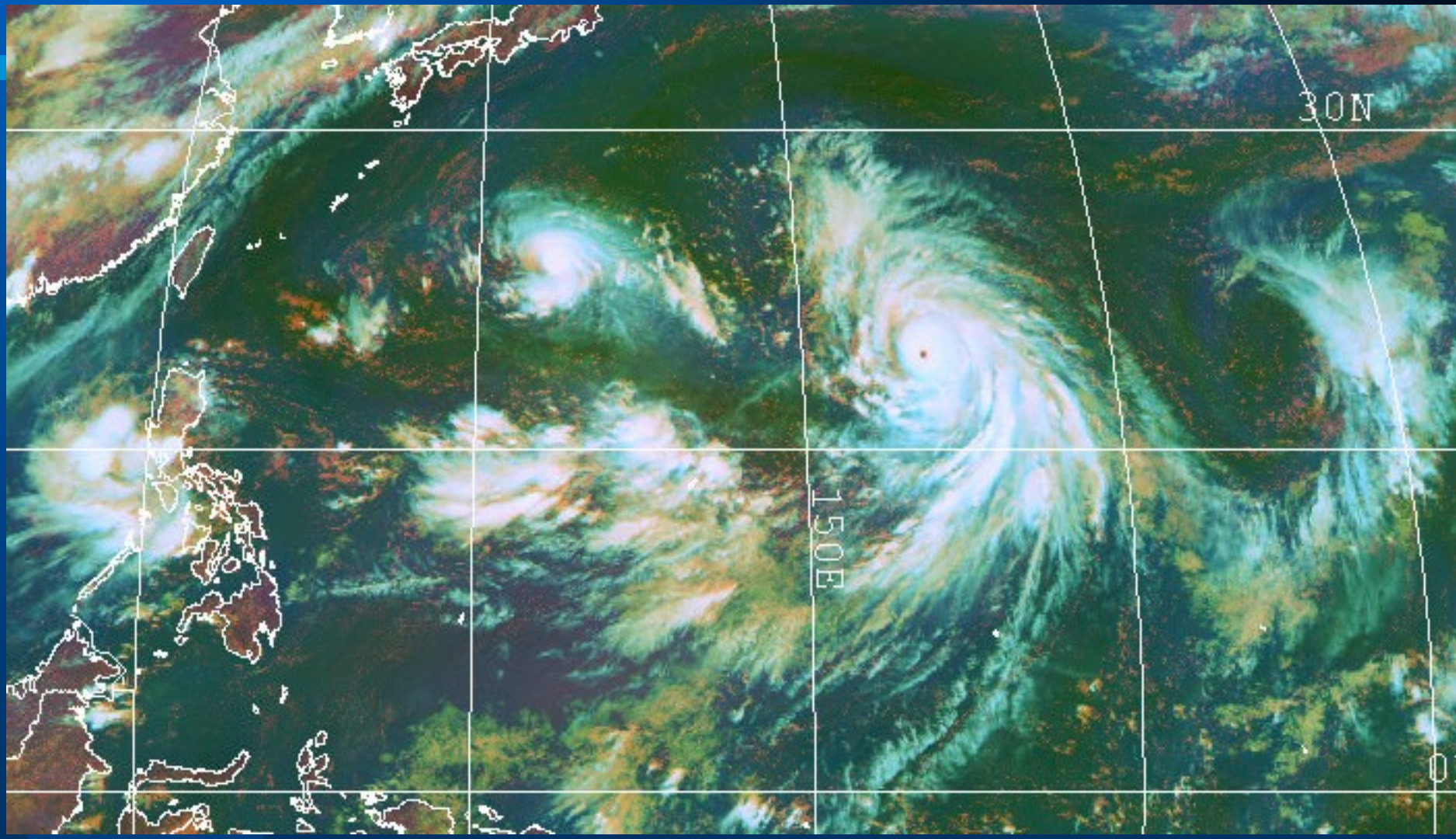
MARSHALL ISLANDS

- Vulnerability to Storm Surge—High
- Vulnerability to Wind—High
- Vulnerability to Flash Flood and Mudslides--Low

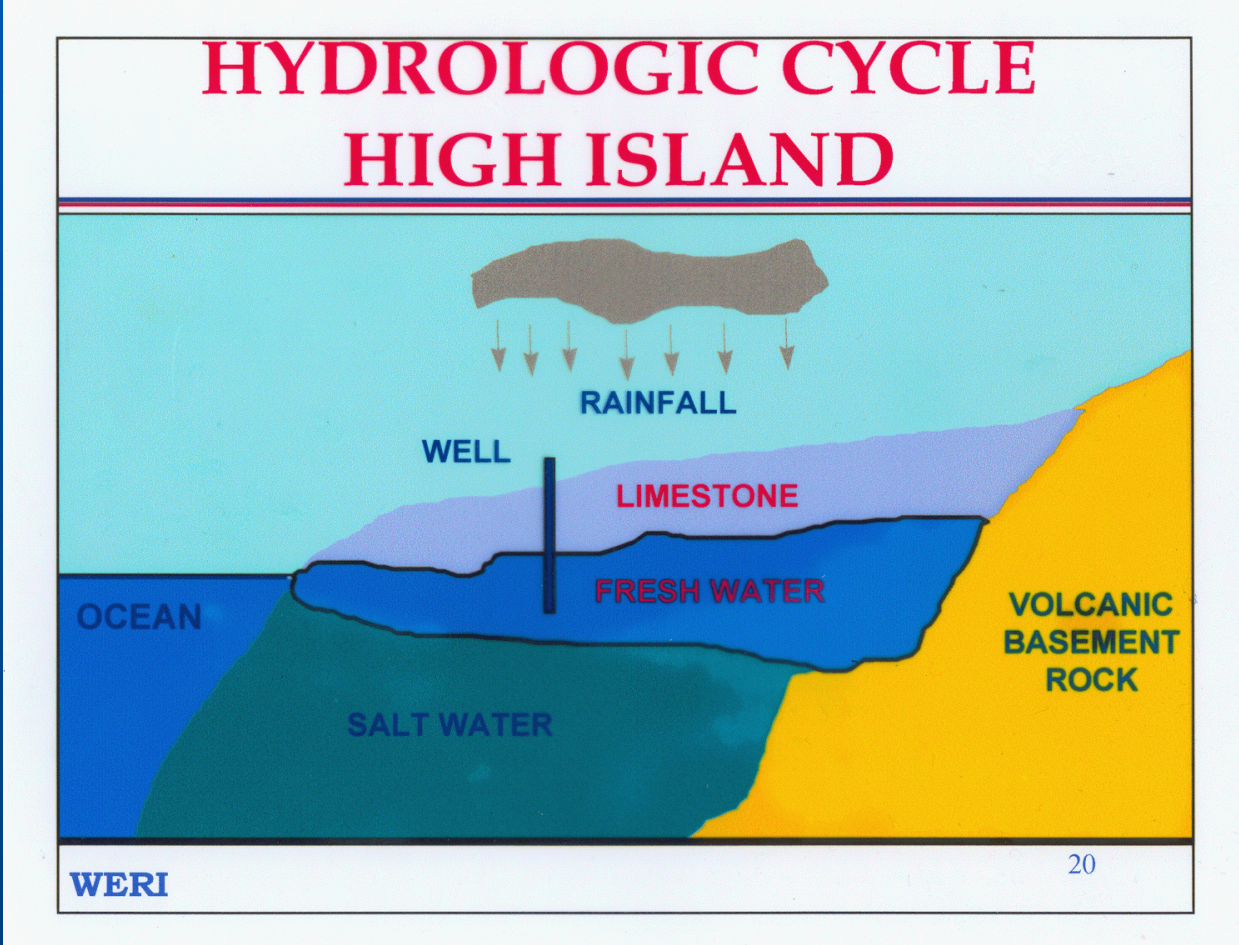
TROPICAL CYCLONE WARNING POINTS—37

- Guam
- CNMI: Saipan, Tinian, Rota, Pagan
- Palau: Koror, Kayangel, Sonsorol
- Yap State: Yap, Ulithi, Fais, Ngulu, Faraulep, Woleai, Satawal
- Chuuk State: Weno/Chuuk Lagoon, Polowot, Fananu, Ulul, Losap, Lukonoch
- Pohnpei State: Pohnpei, Pingalap, Mokil, Pakin, Sapuwafik, Nukuoro
- Kosrae
- Marshall Islands: Majuro, Kwajalein, Ailinglapalap, Jaluit, Wotje, Ujae, Utirik, Mili, Enewetak

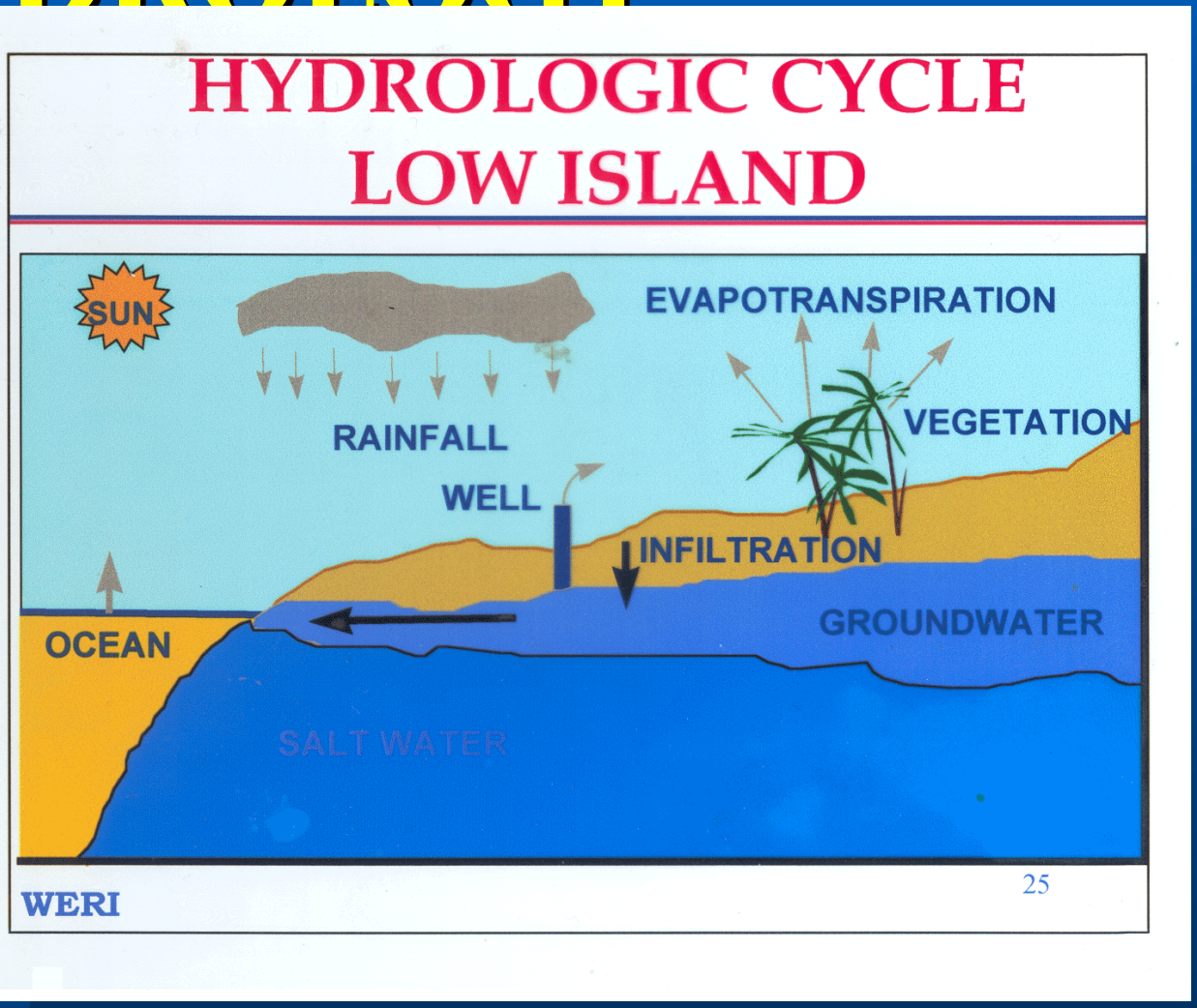
Different Stages of Tropical Cyclone Development



HIGH ISLAND HYDROLOGY



LOW ISLAND HYDROLOGY



Summary 2 (Dickinson, 2009)

Relevant climate statistics:

20th Century sea level rise:
Persistent 1.7 – 1.9 mm/yr (0.066-0.075 in/yr)

Rise of the sea from 1908 to 1999 = 180 mm (~7 in/yr)

Sea level rise 2.5 mm/yr (0.1 in/yr) during 1990s

Sea level rise 4 mm/yr (0.16 in/yr) present decade !?

Crossover dates (when high tides will routinely flood atolls)

Later half of 21st Century for future rapid rise (10 mm/yr) (0.4 in/yr)

First half of 22nd Century for a slower rise (5 mm/yr) (0.2 in/yr)